

The New PFRP Tag: Using Stable Isotope Techniques to Better Understand the Trophic Ecology and Migration Patterns of Tropical Tunas

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Oceanographic Setting: Equatorial Pacific Ocean

Trade winds generally blow to the west across the equatorial Pacific Ocean, piling up warm surface water in the west. In addition, there is a divergence of surface water at the equator due to Ekman transport away from this region. These forces set up a strong upwelling zone that extends westward from the coast of South America. This upwelling zone eventually encounters a large pool of warmer water in the west warm pool-cold tongue system (WPCT) (Figure 1).

The eastern cold-tongue system is characterized by high levels of primary production, whereas the western warm pool, a region that supports highly productive tuna populations, has lower levels of primary production. Tuna forage accumulates in the convergence zone between the warm pool and equatorial upwelling boundary.

Lehodey et al. (1997) demonstrated that movements of tuna populations are linked to large zonal shifts of the WPCT boundary that are driven by inter-annual variability in the trade wind strength (i.e., ENSO events). Within this dynamic WPCT system, the objectives of our PFRP study are to 1) define the trophic structure of the pelagic ecosystem in different regions and 2) establish isotope-derived, biogeography of pelagic predators.

By doing so, we will establish the major ecosystem linkages in the equatorial Pacific and gain insight into how energy and organic matter flow through the upper trophic levels. Finally, the information from our first two goals will form the basis for identifying natural isotope "tags" useful to 3) characterize regional residency and migration patterns of tropical tunas and other apex predators.

Stable Isotopes Techniques

Knowledge of the trophic ecology of pelagic fishes has historically been derived from diet studies. However, stomach contents provide only a relative snapshot of the most recent foraging event. Stable isotope values of an organism's tissues have been used as an alternative and complimentary tool to provide information on the time-integrated, assimilated diet. Furthermore, isotopic compositions of fish tissues can serve as internal chemical tags that incorporate and integrate information on their movements and foraging habitat. These

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TAO/TRITON Monthly Data September 2005

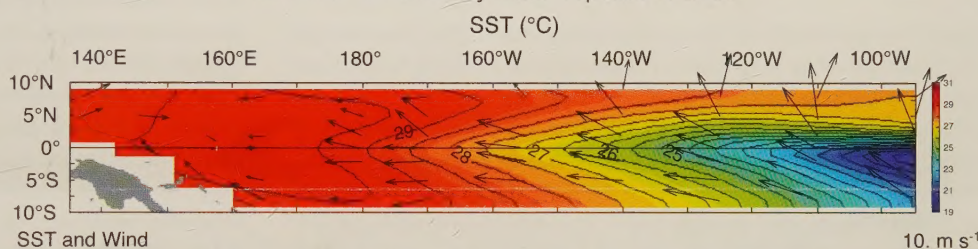


Figure 1. Warm pool-cold tongue (WPCT) equatorial Pacific system. The colors indicate the monthly average surface sea temperature (°C) and the vectors indicate average wind speeds (m s^{-1}) collected from the Tropical Atmospheric Ocean (TAO) project's equatorial moorings (PMEL, NOAA).

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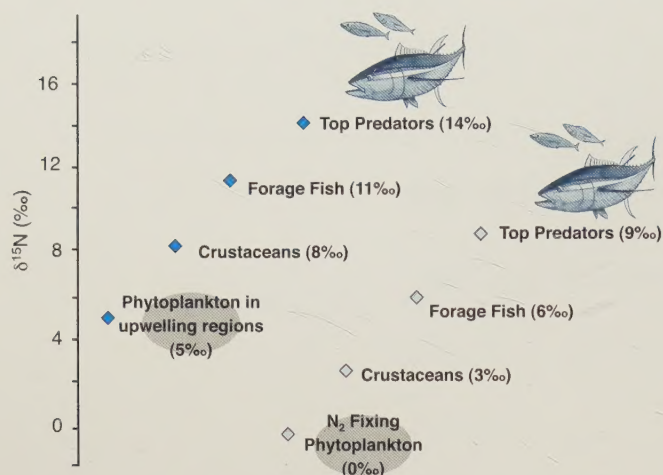


Figure 2. The effect of a change in the isotope baseline on the $\delta^{15}\text{N}$ values of consumers in a simplified food web. The difference between a consumer and its prey is ~ 3 ‰. Dark blue symbols indicate the isotope values of consumers foraging in an upwelling region. Light blue symbols indicate the isotope values of the same consumers foraging in a region fueled by nitrogen fixation.

assertions are based on the simple observation that the isotopic composition of an organism's tissues reflects its food or nutrient sources (Peterson and Fry 1987).

At each trophic level, an increase of ~ 3 units (expressed in stable isotope analysis as ‰ notation) has been observed in the nitrogen isotope ratios ($\delta^{15}\text{N}$) of consumer's tissues relative to their diet (Deniro and Epstein 1981). An important qualification is that the $\delta^{15}\text{N}$ value of a consumer is a function of both the trophic level of that consumer and the $\delta^{15}\text{N}$ at the base of the food web.

At the base of the food web, the primary producers' $\delta^{15}\text{N}$ values are dependent upon the isotope values of their nutrient source (e.g., denitrified nitrate vs. dinitrogen) and the size of the nutrient pool, and degree to which they drawdown the nitrogen pool (Altabet 2001). In turn, both the nutrient source and the biological nutrient uptake are affected by physical and chemical oceanographic processes. For example, in upwelling regions deep nitrate, which has a relatively constant $\delta^{15}\text{N}$ value of ~ 5 ‰, is delivered to the euphotic zone where it is available for biological uptake.

Alternatively, in areas where the water column is highly stratified and nutrients are limiting, nitrogen fixation might play an important role. The $\delta^{15}\text{N}$ value of biologically fixed N_2 is near 0 ‰ (e.g., Dore et al. 2002). As the primary production in these contrasting systems is incorporated and transferred through the food webs, the consumers foraging in these regions will exhibit the $\delta^{15}\text{N}$ values of the nutrient subsidy (Figure 2). Accordingly, we are putting a great emphasis on determining the isotope baseline for the dynamic WPCT system.

Isotope Biogeography

Our isotope dataset for the equatorial Pacific Ocean consists of a few thousand tissue samples of upper-trophic-level preda-

tors and their prey, providing both spatially explicit patterns of trophic dynamics and information on movement patterns. Once maps have been established for different pelagic predators, we will then have a tool to examine changes in the trophic ecology among species. More specifically, after normalizing the $\delta^{15}\text{N}$ values for each species and comparing two of these species isotope maps, anomalous regions will indicate divergences in organisms' foraging behavior and/or movement patterns.

For example, bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) tuna display different $\delta^{15}\text{N}$ spatial distributions in the WPCT system. The $\delta^{15}\text{N}$ spatial patterns of these two species suggest that in the central and eastern tropical Pacific (ETP), bigeye tuna forage more exclusively near the equator than yellowfin tuna. Therefore, isotope cartography can be a powerful tool to examine differences in the foraging strategies of apex predators in the open ocean.

Traditionally, small- and large-scale movements of tuna have been examined using catch statistics, conventional tag and release studies, and tracking studies of fish carrying ultrasonic or electronic tags. Pelagic fish acquire natural isotope signals from their diets, and this isotope tag reflects the diet integrated over a time period constrained by the turnover of the body tissues (Fry and Arnold 1982).

Thus, tissues with different turnover rates can provide an archive of feeding and migration history. Diet shift experiments were conducted on captive juvenile yellowfin tuna at the Hawai'i Institute of Marine Biology to determine tissue turnover rates. The yellowfin white muscle tissue (WMT) had a half-life of approximately 40 days (Graham et al. unpublished data). Therefore, the $\delta^{15}\text{N}$ maps indicate a trophic history of about 5 months for yellowfin tuna.

Within the WPCT system, regional $\delta^{15}\text{N}$ spatial variability is very high for the tropical tunas, and thus, our initial isotope maps for those species indicate a high level of regional residency (Figure 3). To illustrate, if a predator migrated extensively, we would expect little geographic isotopic variation because any regional $\delta^{15}\text{N}$ differences (due to shifts in food web structure or nutrient subsidies) would be integrated over space and time. In this isotope cartography context, geographically anomalous $\delta^{15}\text{N}$ values are an excellent indicator of recent movements (e.g., Figure 3, yellow cell at 168°W and 9°S). By coupling anomalous $\delta^{15}\text{N}$ values with our tissue turnover rates, we will be able to define the likely foraging area of that consumer. Finally, tuna movement patterns interpreted from isotope ratios will be corroborated with existing tag-release data to provide population-level migration patterns of apex predators in the WPCT system.

A Novel Tool: Analyzing Isotope Compositions of Individual Compounds†

What is driving the $\delta^{15}\text{N}$ variability in the equatorial Pacific Ocean? Does the isotopic composition at the base of the food web vary by region, or do different regions have different food web

structure, with some more complex than others? The answers to these questions have been hard to determine, but can be addressed using compound-specific isotope analysis (CSIA) of individual amino acids in the tissues of consumers (Fantle et al. 1999; McClelland and Montoya 2002).

There are two general groups of amino acids, essential and nonessential. Essential amino acids (EAA), which are only produced by primary producers, are incorporated directly from dietary sources into consumers with little alteration in $\delta^{15}\text{N}$ values. Nonessential amino acids (NAA) are biosynthesized by animal consumers, exhibit a trophic-related stepwise-enrichment, and reflect the trophic level of the consumer. Thus, by analyzing the isotopic composition of EAA and NAA in a single sample, the isotope baseline and the consumer's trophic level can be accurately measured.

We tested the applicability of this method to our study by analyzing the $\delta^{15}\text{N}$ of individual amino acids in the WMT of yellowfin tuna from the ETP. The $\delta^{15}\text{N}$ of bulk WMT samples increased considerably from $\sim 10^\circ\text{S}$ to $\sim 20^\circ\text{N}$ in the ETP (Figure 3). If only the trophic level of yellowfin tuna changed with latitude in the ETP, then one would expect EAA $\delta^{15}\text{N}$ values to vary little with latitude and the differences between the $\delta^{15}\text{N}$ of EAA and NAA to increase to the north. If the trophic level of the yellowfin tuna remained constant over the region, then the EAA $\delta^{15}\text{N}$ values should parallel those of bulk WMT and EAA versus latitude.

Our results reveal that the $\delta^{15}\text{N}$ of EAA and NAA in these tuna tissues parallel the bulk $\delta^{15}\text{N}$ values, indicating an increase in the $\delta^{15}\text{N}$ of nitrogenous nutrients moving to the north and not a change in trophic level of the predator. These isotope baseline shifts incorporated into the tissues of mobile tuna in the ETP have a remarkable degree of overlap with the $\delta^{15}\text{N}$ patterns of organic matter analyzed from ETP sediments (Farrell et al. 1995). Previous research has demonstrated that the isotope baseline signal generated in the surface waters is exported and preserved in deep-sea sediments (Farrell et al. 1995; Altabet 2001).

Thus, the $\delta^{15}\text{N}$ overlap between tuna and sediments in the ETP strongly suggests that although tuna are capable of basin-wide movements in the equatorial Pacific, there is a large degree of regional residency. This preliminary finding based on isotope techniques is consistent with some tagging studies that show little overall directional migration for tunas (e.g., BET in the Coral Sea, Gunn et al. 2005). By coupling isotope cartography, CSIA amino acid research, and existing isotope baseline datasets we can now examine regional and basin-wide movement patterns of predators throughout the WPCT system.

Improved understanding of marine food webs is necessary to address concerns that fisheries and climate change alter the

(continued on page 12)

Economic Assessment of Open Fishing Tournaments in Hawai'i

Minling Pan, Adam Griesemer, and Rusyan Jill Mamiit

Recreational fishing is a popular outdoor sport with more than 50 million participants in the United States (U.S. Congress 2004). One of the coastal states, Hawai'i, has a long-standing history of recreational fishing. Tournament fishing, a competition style of fishing, is a popular activity in Hawai'i and attracts thousands of local residents and tourists. Most of the fishing tournaments in Hawai'i are open to all interested anglers, while some are restricted to club members.

Despite the relative cultural and economic significance of recreational fishing, efforts to monitor economic and environmental impacts remain secondary to the commercial fisheries. To understand the social and economic dimensions and the impact of tournament fishing on the state economy, this study investigates the clientele of open boat-fishing tournaments in Hawai'i. A survey was designed to collect primary economic data from the anglers. The information is necessary to assist policymakers in realizing the economic potentials involved with open boat-fishing tournaments and associated tourism, as well as help in their decisions concerning fishery management in Hawai'i. A total of 800 survey forms were sent out to the anglers at 10 selected fishing tournaments in Hawai'i in 2004, and 317 were returned with usable information. Based on

the initial analysis of the returned surveys, this report provides a summary of the preliminary findings.

Anglers' Profile and Attitude

Table 1 shows the years and frequency of participation in the open boat-fishing tournaments in Hawai'i. On average, the anglers have eight years of fishing tournament experience. About 20 percent of the anglers have only one year of participation. While the anglers participated in two tournaments per year, on average, about 50 percent of the anglers have participated in only one tournament. Also, 82 percent of the anglers show an interest in returning.

Based on the overall gender information from the survey, males dominate most events as shown by 60 percent male participation in open fishing tournaments (Table 1). The presence of an all-female tournament, Huggo's Wahine, explains the relatively big fraction of females in a traditionally male-dominated sport in Hawai'i. Without

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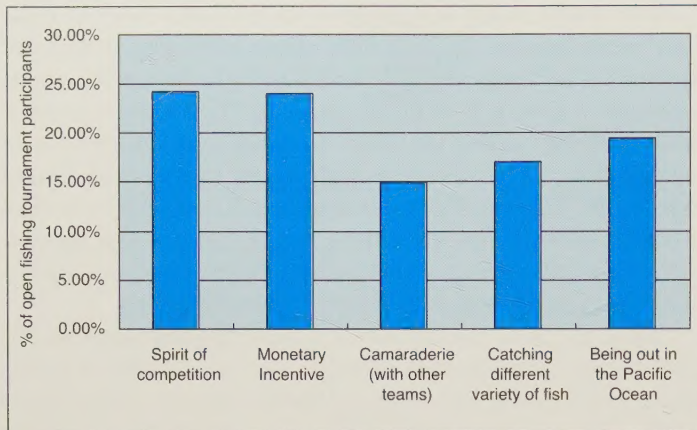


Figure 1. Factors motivating anglers to participate in tournaments in Hawai'i ($n = 292$).

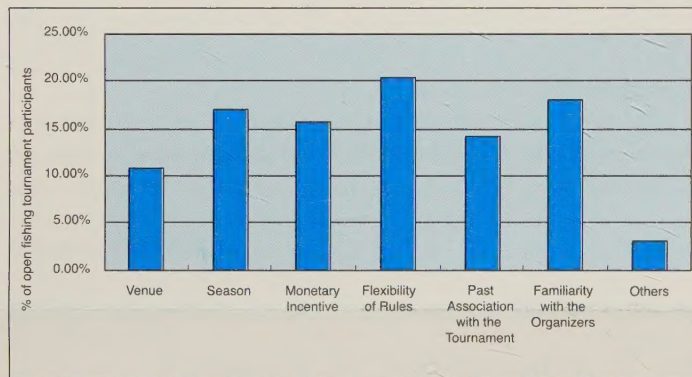


Figure 2. Factors affecting participation in fishing tournaments ($n = 317$).

taking into consideration the number of anglers in the Huggo's Wahine, males account for 82 percent of the total anglers.

Open fishing-tournament anglers come from a diverse range of ethnicity with 54 percent Caucasian (including Hispanic) as the most represented ethnic group (Table 1). Hawaiians made up 15 percent of open fishing-tournament anglers. Interestingly, although Asians make up 42 percent of Hawai'i's population (State of Hawaii DBEDT 2004), only 14 percent of the anglers are Asian.

The income distribution among open fishing-tournament anglers shows that 25 percent of the anglers have an annual household income of more than \$110,000. The household income shows that open fishing tournaments attract anglers with a relatively higher annual income. The findings confirm the results of studies from other regions (Ditton et al. 2000; Milon 2000; Ditton and Stoll 2003), which demonstrate that a majority of the clientele for recreational fishing are high-income individuals. This study in Hawai'i reveals that out-of-state anglers have a high annual income as shown by 55 percent with income greater than \$110,000.

Figure 1 shows the factors that encourage anglers to participate in fishing tournaments in Hawai'i. When asked *how important were the factors shown in Figure 1 in their decision to fish in Hawai'i fishing tournaments*, "spirit of competition" and "monetary (cash

Table 1. Number of years and frequency of participation.

Fishing Participation	# of Tournaments Participated in the last 12 months	# of Years Participating in Open Fishing Tournaments in Hawai'i
Average	2	8
Minimum	1	1
Maximum	16	50

Table 2. Summary of anglers' demographic and main economic characteristics.

Characteristics	Category	Anglers	
		Frequency	%
Gender	Male	188	60
	Female	123	40
Ethnicity	Asian	37	14
	Caucasian (incl. Hispanic)	139	54
	Hawaiian	38	15
	Pacific Islander	4	2
	Others	39	15
Place of Residence	On-island	212	70
	Off-island	11	4
	Out-of-state	79	26
Annual Household Income	< \$30,000	18	7
	\$30,001–\$50,000	55	21
	\$50,001–\$70,000	55	21
	\$70,001–\$90,000	30	11
	\$90,001–\$110,000	43	16
	\$110,001–\$130,000	20	7
	> \$130,000	47	18
Boat Ownership	Boat Owners	124	40
	Non-boat Owners	187	60
Membership in Local Fishing Clubs	Member	33	12
	Non-member	239	88

prize) incentives" were the main motivating factors for anglers to take part in Hawai'i fishing competitions. Also, "communion with nature" by being out in the Pacific Ocean is an important factor to most of the anglers.

When asked about the *important factors that anglers take into consideration in participating in a particular fishing tournament* in general, "game rules and regulations," "association with the tournament organizers" and "tournament schedule" rank among the most prominent factors (Figure 2).

In findings similar to Ditton et al. (2000), the majority of the anglers (72 percent) reported targeting one particular species (Table 3) because many of the fishing tournaments in Hawai'i award cash prizes to single species (e.g., Big Island Marlin Tournament, Skins Marlin Derby and the World Cup Blue Marlin Championship). This substantiates the previous finding that anglers are motivated by monetary rewards because a majority of the tournaments in Hawai'i are focused on targeting a specific species. Pelagic fish species, such as ahi (*Thunnus albacare* and *Thunnus obesus*), mahimahi (*Coryphaena hippurus*), marlin (*Makaira indica*, *Makaira nigricans*, and *Tetrapturus audax*), and

ono (*Acanthocybium solandri*), compose the list of target species frequently sought by open fishing-tournament anglers.

Approximately 89 percent of the anglers support "catch and release" practice. Interestingly, anglers who do not catch fish during competitions had a lower percentage rate of support for "catch and release." Only 79 percent of the anglers who do not catch fish during fishing competitions in Hawai'i advocate the "catch and release" practice.

Tournament Costs and Angler Expenditures

Compared to non-tournament fishing trips, anglers spend more money on a tournament-fishing trip. One of the main expenditures for an open fishing-tournament participant is the tournament entry fee. For an angler who traveled from other islands or other states, the expenses of chartering a boat and travel are additional expenditures. In general, an angler has two portions of trip expenditures. One portion is the expenditures that usually are shared with other team members and the other portion is the personal expenditures.

The major team expenditures incurred by the anglers include entry fees, charter fees, fuel for boat, and ice, food and drink expenses while onboard. Figure 3 shows that entry fees account for 50 percent of the team expenditures for an angler who charters a boat, and 75 percent of that for an angler who does not charter a boat. Personal expenditures include expenses accumulated by the anglers based solely on their personal prerogative and uninfluenced by any means from other team members (e.g., side bets, fishing gear, bait, food after the tournament, souvenirs and

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UPCOMING EVENTS

North Pacific Marine Science Organization (PICES)/ Global Ocean Ecosystems Dynamics (GLOBEC) Symposium on Climate Variability and Ecosystem Impacts on the North Pacific: A Basin-Scale Synthesis

April 19-21, 2006, Ala Moana Hotel, Honolulu

Contact: North Pacific Marine Science Organization

Secretariat at secretariat@PICES.int

Online information: <http://www.pices.int>

American Geophysical Union (AGU) Joint Assembly

May 23-26, 2006, Baltimore Convention Center

Contact: AGU Meetings Department at ja-help@agu.org

(subject: 2006 Joint Assembly) or +1-800-966-2481,
ext. 333 or +1-202-777-7330

Online information: <http://www.agu.org/>

American Society of Limnology and Oceanography (ASLO) 2006 Summer Meeting

June 4-9, 2006, Victoria, British Columbia, Canada

Contact: Helen Schneider Lemay at business@aslo.org or

(254) 399-9635 or Toll Free: (800) 929-ASLO

Online information: www.aslo.org

74th Inter-American Tropical Tuna Commission (IATTC) Meeting

June 26-30, 2006, Busan, Korea

Contact: Inter-American Tropical Tuna

Commission at Webmaster@iatct.org

Online information: www.iatct.org

Western and Central Pacific Fisheries Commission Scientific Committee

August 7-18, 2006, Manila, Philippines

Contact: Western and Central Pacific Fisheries

Commission at wcpfc@mail.fm

Online information: <http://wcpfc.org>

Western and Central Pacific Fisheries Commission Northern Committee

September 11-13, 2006, Tokyo, Japan

Contact: Western and Central Pacific Fisheries

Commission at wcpfc@mail.fm

Online information: <http://wcpfc.org>

Western and Central Pacific Fisheries Commission Technical and Compliance Committee

September 28-October 3, 2006, Brisbane, Australia

Contact: Western and Central Pacific Fisheries

Commission at wcpfc@mail.fm

Online information: <http://wcpfc.org>

Western and Central Pacific Fisheries Commission

December 11-15, 2006, Apia, Samoa

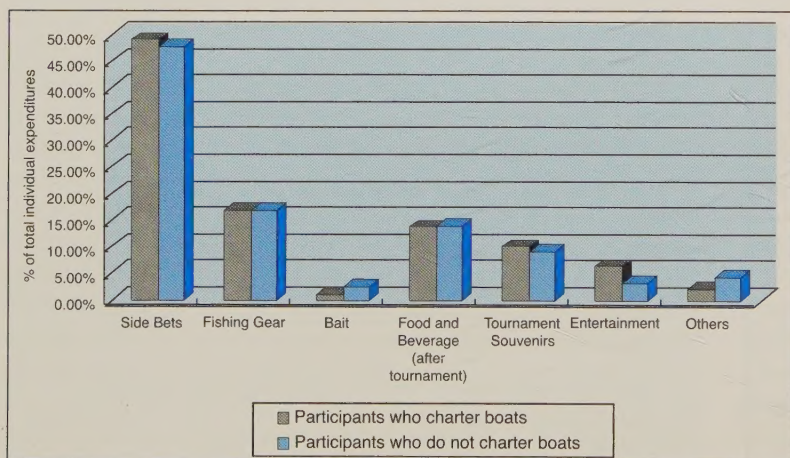
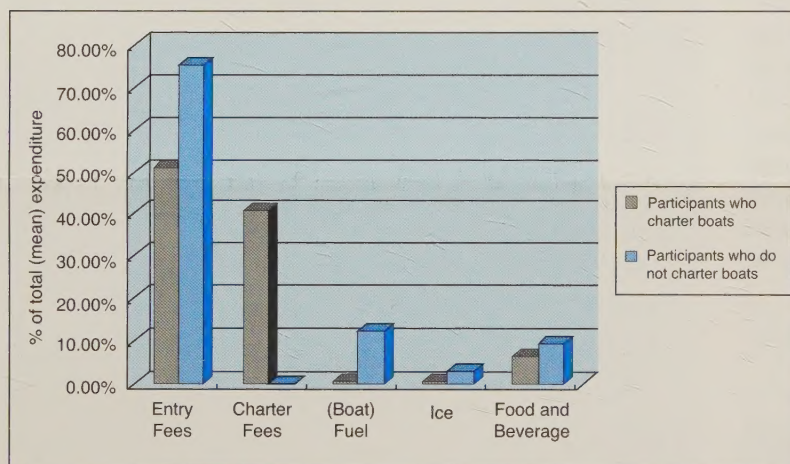
Contact: Western and Central Pacific Fisheries

Commission at wcpfc@mail.fm

Online information: <http://wcpfc.org>

Table 3. Target species of interest among tournament anglers.

Target Species	Anglers who catch fish during tournaments		Anglers who do not catch fish during tournaments	
	Frequency	percent (%)	Frequency	percent (%)
No Target Species	41	24	42	42
One Species	87	49	40	40
Marlin	70	80	31	78
Ahi	14	16	8	20
Others	3	4	1	2
Multiple Species	49	27	17	18
Marlin	38	78	14	82
Ahi	34	69	15	88
Ono	16	33	6	35
Mahi-mahi	17	35	3	18
Aku	5	10	0	0
Others	6	12	3	18



(top) Figure 3. Comparison of team expenditures among anglers ($n = 262$).

(bottom) Figure 4. Distribution of personal expenditures between anglers ($n = 262$).

entertainment). Side bets account for 50 percent of the personal expenditures (Figure 4). Each angler's tournament trip expenditure equals the total of the average of team expenditure of each member plus the personal expenditures.

In addition, the different expenditures structure between charter boat users and non-charter boat users necessitates analyzing their expenditures separately. This approach allowed for a more accurate depiction of the expenditures incurred by recreational anglers in Hawai'i.

Based on the team and personal expenditure distribution shown in Figures 3 and 4, each angler who charters a boat spends an estimated average of \$1,492 per tournament. Each angler who did not charter or rent a boat during fishing tournaments spends an average of \$868. In other words, a four-member team who charter a boat spends about \$5,968 on each tournament trip, while a team who using its own boat (or one that is owned by a team member) spends about \$3,472 on each tournament trip. These estimates include each member's personal and team expenditures.

In Hawai'i, a number of anglers participate in multiple fishing tournaments during a tournament season, which is from April to September. The Maui Jim Hawai'i Marlin Tournament Series, for example, included nine tournaments in 2004. The option of participating in multiple tournaments may provide anglers a higher probability of obtaining the most coveted cash or in-kind rewards. It also allows anglers, especially the out-of-state anglers, to maximize their trip to Hawai'i by providing the opportunity to fish more at a lower cost.

Compared to the expenditures incurred by anglers who participate in single tournaments, multiple-tournament anglers, in general, spend more in one fishing tournament season. A four-member team participating in multiple fishing tournaments can incur a mean expenditure of \$12,320, which includes both team and personal expenditures.

Non-Tournament-Related Expenditures

Out-of-state and off-island tournament anglers can incur additional, direct non-tournament-related expenses, such as hotel accommodations, car rentals, and entrance fees to tourist destinations, among others. In most cases, out-of-state and off-island anglers bring family members and friends to the competition. Family members who do not compete in the tournament may participate in other activities arranged by the tournament organizers.

On average, out-of-state fishing-tournament anglers bring two family members when they take part in fishing competitions in Hawai'i. Out-of-state anglers stayed

an average of 10 days in Hawai'i. Common expenses of out-of-state anglers and their families include airfare, car rental, lodging, tips, entrance fees to tourist destinations, food and souvenirs, among others. The daily non-tournament related expenditures can amount to \$179 per person or \$536 per family (excluding airfare).

Total Economic Impact

The open boat-fishing tournaments clearly provide significant annual revenue to the state economy. This study plans to estimate

annually a total economic impact to the local economy by extending the survey sample to the population level at the next stage of analysis.

PFRP

Minling Pan is an industry economist at the Pacific Islands Fisheries Science Center. Adam Griesemer is a JIMAR fishery economic research surveyor. Rusyan Jill Mamiit is a JIMAR fishery economic researcher.

Analyses of Incidental Catch and Bycatch by the Hawai'i-based Longline Fishery

William A. Walsh

PFRP-sponsored research has been conducted at the Pacific Islands Fisheries Science Center (PIFSC) of NOAA Fisheries for several years in an effort to increase understanding of bycatch, especially blue shark, *Prionace glauca*, and incidental catch of istio-phorid billfishes (i.e., marlins) by the Hawai'i-based longline fishery. In the case of blue shark, the major concerns were under- or non-reporting of a species that can be very numerous in the catch. With billfishes the concern was the accuracy of identifications of superficially similar fishes that typically comprise a relatively small fraction of the catch (ca. 5%, numerical basis).

All of this work entailed fitting statistical models to catch data reported by fishery observers and then using these models as comparison standards to judge the accuracy of commercial logbooks. Sales records from the public fish auction conducted by the United Fishing Agency, Ltd., Honolulu, were also used as an independent means for verification of analytical results with the billfishes. To date, this work has yielded three peer-reviewed papers (Walsh and Kleiber 2001; Walsh et al. 2002; Walsh et al. 2005) and a fourth in review (Walsh et al., submitted to the *Bulletin of Marine Science*).

A presentation to the PFRP workshop in November 2005 included results from the submitted manuscript, preliminary results from a manuscript in preparation, and a brief summary of other recent activities. The submitted work (Figure 1), presented at the Fourth International Billfish Symposium in Avalon, California, in November 2005, described improvements in statistical models of blue marlin, *Makaira nigricans*, catches that yielded greater predictive accuracy and comprehensibility with little loss of precision relative to previous work (Walsh 2002; Walsh et al. 2005).

The very high correlation ($r = 0.861$; $df = 118$; $P < 0.001$) demonstrated that predictions from a relatively simple statistical model fitted to fishery observer data corresponded closely to the

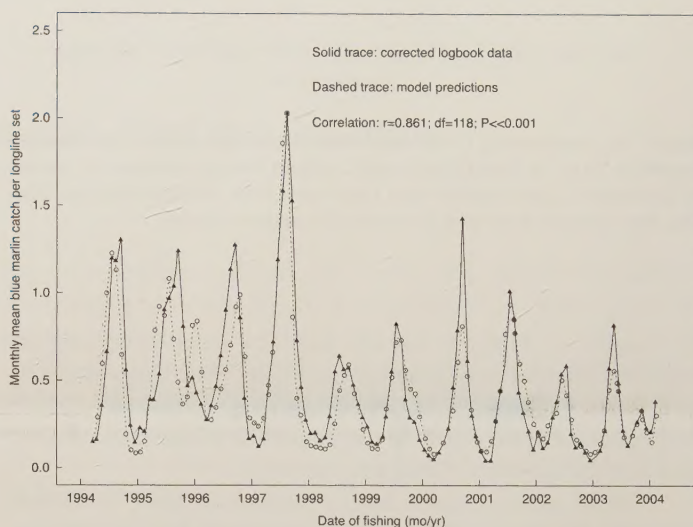


Figure 1. Monthly mean corrected blue marlin catch per set in relation to monthly mean predicted catch per set for tuna-targeted trips without fishery observers by vessels of the Hawai'i-based longline fleet from March 1994 through February 2004.

corrected catch trends on unobserved sets as reported in logbooks. In effect, a statistical model becomes a "surrogate observer."

Because this approach has already attained acceptance concerning bycatch, with favorable citations regarding its potential to increase accuracy and precision in logbook reporting programs having been put forward by both the National Marine Fisheries Service (NMFS) (2003) and Oceana (Babcock et al. 2003), a nongovernmental conservation organization that has critiqued NMFS observer programs, it seems reasonable to suggest that this PFRP-sponsored work will also prove useful with incidental billfish catches.

"His (Walsh) work complements the normal Q/C work done by NOAA Fisheries on both logbook and observer data for the Hawai'i longline fishery by identifying our weaknesses and suggesting ways to correct them (e.g., better species identification training

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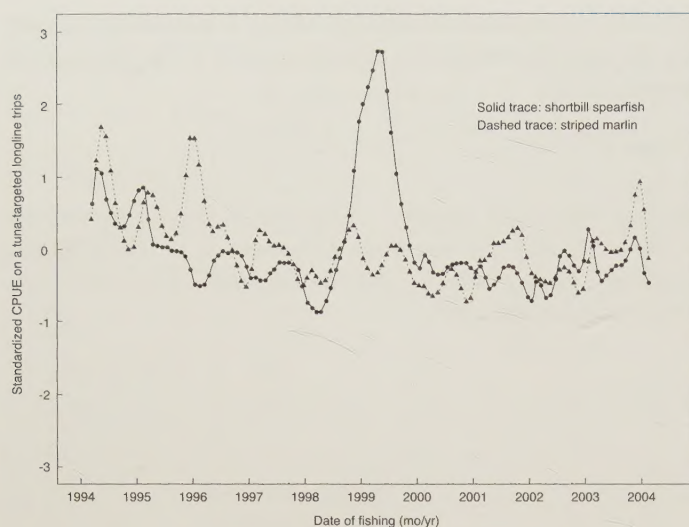


Figure 2a. Standardized CPUE time series for striped marlin and shortbill spearfish taken on tuna-targeted trips without fishery observers by vessels of the Hawai'i-based longline fleet from March 1994 through February 2004. The time series is detrended to remove the seasonal signal.

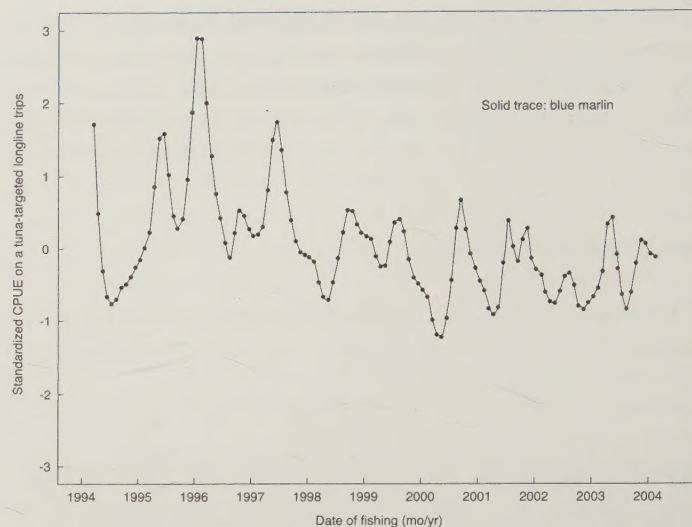


Figure 2b. Standardized CPUE time series for blue marlin taken on tuna-targeted trips without fishery observers by vessels of the Hawai'i-based longline fleet from March 1994 through February 2004. The time series is detrended to remove the seasonal signal. Note the reduced response axis relative to Figure 2a.

for longline captains). It has also yielded a much more accurate scientific time-series of longline catch data that is now available to a variety of researchers working in a range of disciplines, from stock assessment to ecosystem simulations to economic dynamics," said Samuel G. Pooley, director of the PIFSC.

"Use of catch estimates from a research database is valuable because it increases confidence in the results, and it also helps the U.S. scientific delegation in relation to those from other countries because they know that we are providing data that was screened by methods published in the peer-reviewed literature," said Gerard T. DiNardo, PIFSC supervisory research fishery biologist and director of the North Pacific Ocean stock assessment of striped marlin, *Tetrapturus audax*, conducted in November 2005.

Potential users of the research database may contact Brent Miyamoto, PIFSC Scientific Information Services, regarding access at Brent.Miyamoto@noaa.gov.

The results in preparation for publication consisted of analyses of commercial longline logbook accuracy for four billfishes, which were intended to complement the published results with blue marlin. This work revealed several types of species misidentifications that contribute to reporting bias (Table 1) for this guild of ecologically and economically important, closely related fishes.

For example, striped marlin logged as blue represented 65% of the increment in the corrected catch total for the former species (9,793 of 15,062 fish), while others logged as black marlin, *M. indica*, represented an additional 16% (2,368 of 15,062 fish). Blue marlin, in contrast, exhibited a different pattern, with a large decrement (-9,811 fish) caused by corrections to striped marlin, but an increment (1,468 fish) from corrected identifications of fish

logged as blacks. Many of the remaining corrections were more complex, with Species A misidentified as Species B, which was in turn misidentified as Species C, and so forth.

Table 1. Summary of reporting bias for five istiophorid billfishes in logbook reports from the Hawai'i-based longline fishery, March 1994-February 2004.

Species	Nominal catch	Corrected catch	Δ	Δ (%)
Blue marlin	53,480	43,772	-9,708	-18.2
Striped marlin	134,319	149,381	15,062	11.2
Black marlin	5,778	689	-5,089	-88.1
Shortbill spearfish	88,210	89,569	1,359	1.5
Sailfish	4,638	2,749	-1,889	-40.7

It should be noted that these corrections were only performed when verification was possible. Because sales records were not always available, especially in 1994 and 1995, the estimates for over-reporting of black marlin and sailfish, *Istiophorus platypterus*, in particular, are conservative.

The recent activities entailed use of the corrected data sets to prepare standardized time series plots for blue marlin, striped marlin, and shortbill spearfish, *T. angustirostris*, catch per unit effort (CPUE) on tuna-targeted fishing trips during the 10-year interval from March 1994, at the outset of the Hawaii Longline Observer Program, through February 2004. Tuna-targeted trips were chosen as the longest uninterrupted series in this fishery. These plots (Figure 2) were also adjusted for seasonal effects.

It should be noted that the response axis for striped marlin and shortbill spearfish (Figure 2a) is an order of magnitude greater than that for blue marlin (Figure 2b), reflecting their greater numbers in the catch. The most noteworthy features of these plots are that each species exhibited at least one well-defined and verified peak (shortbill spearfish: late 1998 to mid-1999; striped marlin: late 1995, late 2003; blue marlin: mid-1997).

The data from 1994 are unreliable because most sales records were not available, and the apparent peak for blue marlin in late 1995 to early 1996 probably reflects misidentifications of striped marlin that were also impossible to correct. Nevertheless, it seems reasonable to assert that none of these species exhibited a trend of decline in this fishery during this 10-year period.

Near-term research plans include the intention to use the corrected catch data for these fishes in comparative studies (e.g., in relation to other fisheries or other locales). The aspiration is that both the methodology employed and the results generated in these studies will represent contributions to ecosystem-based fisheries management.

PFRP

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A Short History of Pelagic Fishing in the Mariana Islands

Judith R. Amesbury

Prehistoric Period

The first people to arrive in the Mariana Islands (Figure 1), at least 3,500 years ago, were no doubt skilled pelagic fishermen. They had sailed long distances over open ocean from the islands to the west and southwest. Throughout the long Prehistoric Period (Table 1) before contact with Europeans in AD 1521, they continued to fish for pelagic species.

Proof of the fishing skills of the pre-contact people of the Marianas is found in archaeological excavations, which yield fish bones, some of which can be identified usually to the family level. Fish catches of the past can be quantified not only in terms of the number and weight of bones recovered, but also in terms of the Minimum Number of Individuals (MNI) of fishes represented and the percentages of various families represented. This type of analysis has been performed for a few sites in the Marianas, including two projects on the north coast of Rota (Table 2). Fishes represented in the table are only a small sample of the fishes consumed at the sites.

The MNI are surprisingly small numbers, not because so few fish were caught over the millennia, but because only a fraction of the fish remains discarded at a site are preserved in the ground, and only a fraction of the preserved remains are recovered by the archaeologists, and only a fraction of the recovered remains can be identified by the faunal analysts.

Spanish Period

Magellan arrived at Guam in 1521, and Legazpi claimed the islands for Spain in 1565. It was not until over 100 years later that the Spanish colonized Guam in 1668. During those years, other

European explorers visited the islands and praised the sailing, swimming and fishing ability of the Chamorros, as the islanders are now known.

Pelagic fishing during the Prehistoric Period and the first couple hundred years of the Spanish Period depended on the flying proa, the large ocean-going sailing canoe. An idea of the number of proas comes from a narrative of Legazpi's voyage attributed to Father Martin Rada.

Rada reported that more than 400 proas surrounded Legazpi's ships anchored at Umatac, Guam in 1565: "It certainly is something to see how fast they sail and how easily they change direction" (Lévesque 1992:158). Rada also described a boathouse in the village of Umatac that would hold 200 men.

Just before the end of the 16th century and at the beginning of the 17th century individuals motivated by religious zeal jumped ship in the Mariana Islands in order to convert the islanders to Roman Catholicism. Other Spaniards were shipwrecked in the Marianas. Their longer tenure in the islands allowed them to learn more of the customs of the Chamorros.

A lay brother named Fray Juan Pobre de Zamora jumped ship at Rota and spent seven months there in 1602. While in Rota, he was visited by another Spaniard named Sancho, who had survived the shipwreck of the *Santa Margarita* in 1601 and had become the servant of a Chamorro named Suñama, who lived at Pago, Guam. Sancho told the following fish story about his master Suñama to Fray Juan Pobre.

Suñama caught a flying fish and ate the first one raw. With the second flying fish, he baited his hook and hooked a very large billfish (probably a blue marlin) and spent a great deal of time playing

(continued on page 10)

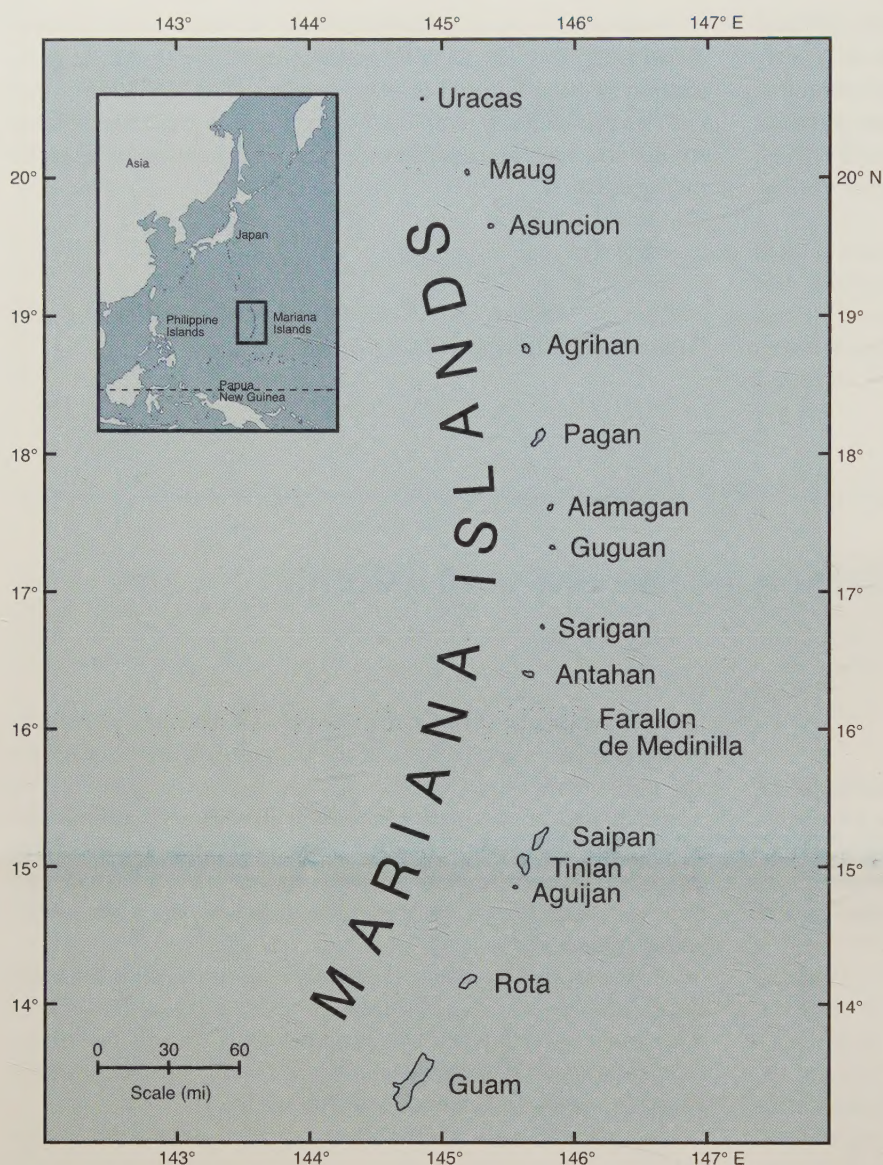


Figure 1. The Mariana Islands. (map courtesy of Barry Smith)

the fish to tire it. A large shark came and seized the billfish. When Suñama did not let go of the line, his boat capsized. He tied his line to the capsized boat and followed the line to the shark, diverted the shark, then brought the billfish back to his boat, which he righted and sailed home flying a woven mat from the masthead to indicate a successful catch. Sancho concluded that the Chamorros were "the most skilled fishermen ever to have been discovered" (Driver 1983:15).

Soon after the Spanish colonized Guam in 1668, hostilities broke out. Open rebellion on the part of the Chamorros against the Spaniards began in 1670, and the Spanish-Chamorro Wars continued for 25 years until 1695. The Spanish burned the villages and boats of the islanders and rounded up fugitives who had fled from Guam to the other islands. They forcibly relo-

cated the islanders into parishes organized around churches in Guam.

The last European voyager to describe the flying proa was Captain Crozet, who anchored at Guam in 1772. However, there is reason to believe that Crozet copied his description from George Anson, who anchored at Tinian in 1742. When Dumont D'Urville first visited the Marianas in 1828, he said the islanders were no longer able to make these canoes. So it appears that the Chamorros no longer used the sailing canoes after the mid-1700s, and no longer fished for pelagic species on a very large scale.

Carolinians, natives of the Caroline Islands south of the Marianas, continued to build and sail similar ocean-going canoes, and a number of Carolinians migrated to the Marianas during the 1800s. The Carolinians probably continued to fish for pelagic species during the 1800s, but information is lacking.

Twentieth Century

Just before the beginning of the 20th century, Spain lost control of the Marianas. Guam was ceded to the U.S. in 1898, and Germany purchased the islands north of Guam in 1899. In 1914 Japan captured all the German-held islands in Micronesia and occupied the Northern Marianas until 1944. Guam was occupied by Japan from 1941 to 1944.

Pelagic fishing in the Marianas was resumed on a relatively large scale for the first time in 150 years or more by the Japanese in Saipan. During the 1920s and 1930s, the Japanese operated a pole-and-line fishery for skipjack and yellowfin tuna. This was the first commercial fishery in the Marianas. Labor was imported from Japan and Okinawa, and the fish was shipped to Japan.

According to statistics obtained from Japan, skipjack catches in Saipan District (Saipan, Tinian, and Rota) peaked at nearly 3,700 metric tons in 1937. Yellowfin catches peaked at 151 metric tons in 1936.

The American capture of Saipan in July 1944 put an end to the Japanese fishery there. All of the boats were either sunk in the harbor or beached and burned. Soon after the end of hostilities, the sunken hulls were raised from the lagoon and reconstructed by Japanese and Okinawan carpenters prior to the repatriation of Japanese nationals in 1946. Four boats were restored to use in Saipan and Tinian, and the fish caught were used to feed the interned civilians.

From 1946 through 1950, three of the same boats were put to use by a cooperative of Carolinian fishermen, known

as the Saipan Fishing Company. Capital for the Saipan Fishing Company came from a small group of Carolinian men who were employed as policemen. One of those policemen was the father of Lino Olopai (Photo 1). The father of Rafael Rangamar (Photo 1) was the captain of one of the boats. Olopai and Rangamar went out on the boats as children and recalled the excitement of pole-and-line fishing in an interview in Saipan in 2005.

Meanwhile in Guam, the U.S. Naval Government decided to teach the Chamorros to fish beyond the reef. From 1933 to 1937, 12 men at a time were trained for a period of three months. For safety's sake, the instruction took place within view of a fishing lookout at Orote Point, and each boat carried trained homing pigeons to carry messages in case of emergency. Offshore fishing did not develop at that time due to a lack of boats.

After World War II, cash was scarce, but as the economy improved in the 1950s and 1960s, the local people in the Marianas began to buy boats and outboard motors and troll for pelagic species. Five species make up 90-95 percent of the trolling catch: mahimahi (*Coryphaena hippurus*), skipjack (*Katsuwonus pelamis*), wahoo (*Acanthocybium solandri*), yellowfin (*Thunnus albacares*), and blue marlin (*Makaira nigricans*).

An economic boom, which began in the late 1980s and continued through most of the 1990s, led to an increase in number of boats. Now hundreds of thousands of pounds of pelagic fish are landed each year. The fishermen of the Marianas have no doubt regained their place among the best pelagic fishermen in the world.

PRFP

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Table 1. The Prehistoric and Historic Periods in Guam and the Commonwealth of the Northern Mariana Islands (CNMI).

Guam	CNMI
Prehistoric Period (about 1500 BC - AD 1521)	Prehistoric Period (about 1500 BC - AD 1521)
Spanish Period (AD 1521 - 1898)	Spanish Period (AD 1521 - 1899)
First American Period (1898 - 1941)	German Period (1899 - 1914)
Japanese Period (1941 - 1944)	Japanese Period (1914 - 1944)
Second American Period (1944 - present)	American Period (1944 - present)



Photo 1. Lino Olopai (left) and Rafael Rangamar at the Seaman's Restaurant, Saipan, in 2005. These men went out on the boats of the Saipan Fishing Company when they were children. (photo by Judith Amesbury)

structure and function of marine ecosystems (e.g., Pauly et al. 1998; Myers and Worm 2003). Selective removal of large predatory fishes from food webs can impart changes in the trophic structure via trophic cascades, defined as inverse patterns in biomass across more than one trophic level in a food web (Carpenter et al. 1985). Therefore, the trophic status of key taxa could be a useful metric of ecosystem change. Using the powerful CSIA method, we will next examine historical changes in the trophic level of archived (museum) samples of pelagic fishes to investigate effects of fisheries removals on the trophic structure of pelagic ecosystems.

PFRP

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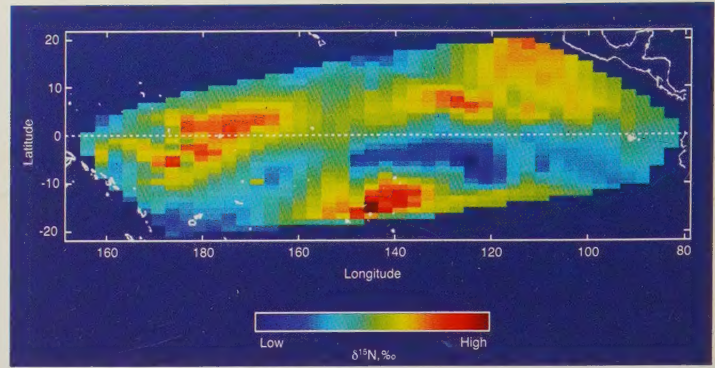


Figure 3. Isotope biogeography of tropical tunas in the equatorial Pacific Ocean. Colors indicate the tropical tuna $\delta^{15}\text{N}$ values, which reflect an organism's foraging history.

† The results of the research described in this section are from the publication: Popp, B. N., Graham, B. S., Olson, R. J., Hannides, C. C. S., Lott, M., López-Ibarra, G., and Galván-Magaña, F. In Press. Insight into the trophic ecology of yellowfin tuna, *Thunnus albacares*, from compound-specific nitrogen isotope analysis of proteinaceous amino acids. In *Isotopes as tracers in ecological change*, eds. T. Dawson and R. Seigwolf. Elsevier.

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